A Housing Energy Management Program Report

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MEDIUM EFFICIENCY NON-CONDENSING FURNACE FIELD STUDY - INSTALLATION REPORT - REPORT NO. 9A

UNDERTAKEN JOINTLY BY THE ONTARIO MINISTRIES OF MUNICIPAL AFFAIRS AND HOUSING AND ENERGY UNDER THE HOUSING ENERGY MANAGEMENT PROGRAM (H.E.M.P.)

PREPARED FOR
THE ONTARIO MINISTRY OF MUNICIPAL AFFAIRS AND HOUSING
HOUSING RENOVATIONS
AND ENERGY CONSERVATION UNIT
BY
UNION GAS LIMITED

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SUMMARY

In June 1983, the Ontario Ministry of Municipal Affairs and Housing entered into discussion with Union Gas Limited concerning the possibility of a joint research project to study high efficiency heating equipment. As a result of these talks, and funding from Ministry of Energy, an agreement to field test several high efficiency non-condensing furnaces was reached. Having completed the installation and commissioning of one such furnace, this report addresses the details of the installation and commissioning of the unit.

The furnace is currently operating and is being monitored. Test results are expected upon completion of the '83/'84 heating season.

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1.0 INTRODUCTION

1.1 Study Agreement

Union Gas Limited and the Ministry of Municipal Affairs and Housing share a mutual interest in the area of energy conservation and more efficient appliances.

High Efficiency Non-Condensing Gas Furnaces have recently entered the residential heating equipment market. Due to the limited performance data available on these products, it was decided to study their performance in realistic field installation tests.

The Ministry of Municipal Affairs and Housing, with funding through the Ministry of Energy HEMP program, and Union Gas entered into an agreement to field test one high efficiency non-condensing furnace. The objectives of the study were "to assess the energy savings, performance and economics through field testing of one high efficiency non-condensing furnace on a retrofit basis in Southwestern Ontario".

1.2 Selection of Test Locations

A multi-criterion selection procedure was used to investigate possible sites at which the furnace would be tested (see Appendix A). One obvious criterion required that the locations must be representative of a "typical" installation. Of particular concern was the size of the house, both in terms of heating load and floor area.

The location selected was a detached, single storey, single family style home with a calculated heat loss of 15.2 KW (see Appendix A for location details). This site was particularly selected because it did not have any existing heating equipment installed. This in itself provided an interesting opportunity to design the heating system (duct work plus heating unit) specifically with the study objectives in mind. The test unit did not have to be matched with the capacity of an existing unit which often is excessively oversized. The furnace was thereby selected in accordance with the house design heat load based on the A.S.H.R.A.E. method of heat load calculations, with chosen oversize factor of approximately 20%.

2.0 FURNACE OPERATION

Although similar to a conventional gas-fired furnace in terms of combustion, heat transfer and air movement, the medium efficiency non-condensing unit does have a few inherent differences.

The most important feature is the introduction of induced draft in the exhaust system. A power exhauster meters the precise air/gas mixture providing efficient combustion and eliminates the loss of heated air up the chimney due to draft hood venting and more significantly the residual heat from the exchanger off-cycle losses. This in turn lends itself to a simplified venting system consisting of flexible steel piping and a specially designed venting terminal.

This feature alone may save, in the opinion of the manufacturer, a considerable amount of energy which would be lost up the chimney of a conventional furnace.

A second energy saving feature is the solid state electronic ignition on the pilot. This ignition system lights the pilot only when heating is required and consequently the manufacturer claims average gas consumption over standing pilot can be reduced by 5 to 7%.

A noteworthy feature of the furnace tested, although not related to increased efficiency, is the two-speed option supply air blower. The blower can be set to operate at low speed for the off-heat mode and high speed for the on-heat mode. Switching is automatic. This option, provided at an extra cost, has particular importance in improving air distribution and reducing heat stratification.

3.0 FIELD TESTING PROCEDURES

3.1 Operations

In establishing a field test methodology, a consensus exists in that a flip/flop procedure is currently the best technique for energy consumption evaluation.

An electric plenum heater, rated at 100% efficiency is to be used as a basis for comparison. The method itself involves operation of both the test equipment and the plenum heater for alternate periods of time. For the purpose of this study, a one week cycling period was chosen.

Data will be recorded when switching from one furnace to the other. Essentially, one is looking to determine the total energy consumption as compared to the usable heat delivered. Metering requirements include gas sub-meters and kilowatt hour (KWH) meters. Necessary weather data, degree day data and local station records information are to be supplied by the Atmospheric Environment Service of Environment Canada and by a Union Gas weather station located in the vicinity.

4.0 INSTALLATION FEATURES

4.1 General Considerations

In proceeding with the furnace installation, it was decided that the contractor(s) on the installation would be given limited instruction and supervision during their work. It was believed this would provide a more "typical" installation in terms of actual fabrication and difficulties which could arise in installing a relatively new piece of equipment. However, in the interest of time and recording accuracy, detailed instructions were to be given as to the installation of metering and any other specific test requirements. This it was felt did not remove from the actual learning experience of installing new heating equipment.

To provide for as typical an installation as possible, the installation was awarded to a local contractor who manifested interest in such a project. Such an individual is invaluable in providing constructive feedback as to installation procedures and equipment operation.

4.2 Gas Equipment

For all intents and purposes, the gas equipment was installed in a conventional manner (See Appendix B).

A lowboy model furnace was selected for space reasons to accomodate the minimum clearance requirement of the plenum heater. Venting was installed through an existing basement window for convenience. This option was made possible by the unique flexible flue pipe venting system of the medium efficiency non-condensing furnace and can represent a substantial savings over conventional venting practices.

4.3 Electrical Equipment

The electrical unit was simply installed in the supply plenum of the gas furnace. It required a 125 Amp capacity and consequently required a 200 Amp. service to the house.

5.0 FURNACE INSTALLATION

5.1 Remarks

Generally, the furnace installation was done quite well, in a neat, professional manner. In discussion with the contractor, the installation of the test equipment proved to be straight forward with no real difficulties encountered. Additional comments by the contractor indicate that he was pleased with the overall construction and design of the equipment.

6.0 MONITORING

6.1 Procedure

In monitoring the equipment, a decision was made to have the home owner cycle the furnace and record the necessary information as per a specific schedule (See Appendix C). This it was felt would provide a convenient, yet reliable means of cycling the equipment. To ensure consistency in the operation and recording of data, an operating package was put together and provided to the home owner. In addition, Union Gas staff were to inspect the site regularly and to review the results of the testing with respect to total energy consumption.

7.0 COMMISSIONING

7.1 Anticipator Settings

The gas furnace was equipped with a simple standard T-86 thermostat. In commissioning both the plenum heater and furnace to operate from the same thermostat it was determined that the higher amperage requirements of the gas furnace was significant in influencing the operation of the thermostat. To avoid continual "adjustment" of the thermostat anticipation for each unit, an isolating circuit was designed and installed. The operation of this circuit was to provide a constant amperage draw through the thermostat. The circuit consists basically of a 20 VA transformer and a relay switch added to the existing thermostat wiring (See Appendix D). This method has been used in other furnace tests and has proven to be very effective in providing a consistent thermostat setting while at the same time guaranteeing proper cycling.

7.2 Metering

In assessing the readability of a standard residential meter, it was felt that one hundred cubic feet (100 cu. ft.) graduations were inadequate for test purposes. The standard meters were therefore re-equipped with one-tenth of a cubic foot (0.1 cu. ft.) digital indices, giving a readability accuracy of plus or minus five-hundredth of a cubic feet (+ 0.05 cu. ft.). This typically represents a daily reading accuracy within the inherent accuracy of the meter. Each index was calibrated on a Union Gas meter prover in order to insure accuracy. A summary of metering and other equipment referenced in the installation diagrams is given in Appendix E.

8.0 CONCLUSIONS

Remarks

With the installation and commissioning trials completed, the test site is currently in operation.

In commissioning the test furnace a few problems did occur.

Initially, the furnace would not fire when the thermostat called for heat. At this time the controls were independant of the electric plenum heater. Troubleshooting operations revealed that the high pressure proving switch was malfunctioning. The problem was corrected by simply replacing the switch.

A second problem was encountered with system mode - control setup through the electrical plenum heater control switch. The gas furnace was seen to run-on continually despite the fact that the thermostat had been satisfied for heat. The unit did shut off only when it reached the maximum allowable high limit temperature.

A voltage reading was taken across the relay coil which in turn controls the gas valve operation. In normal operation, when the thermostat is satisfied for heat it will interrupt the circuit and the gas valve will close. Therefore, no voltage should be recorded across the relay coil after valve shut-off. Our readings indicated 5 to 10 volts were actually across the coil when the thermostat circuit was open explaining why the valve remained energized and stayed open. This did not occur when the furnace was setup independently of the plenum heater control system and consequently the problem was attributed to a fault in the plenum heater circuit board.

It is felt that this situation has potentially hazardous implications in the normal operation of the unit and the problem was discussed with the manufacturer. The exact cause has not yet been determined and will be documented in future reports. Presently the system is arranged with both heating units independ-

ently wired through the same thermostat by way of a double-pole-double-throw switch.

One final complication arose in adjustment of the furnace temperature rise in order to meet the design conditions for both the house and the furnace. Upon initial commissioning of the gas furnace a temperature rise of approximately 17 Deg. C. was read. Both the house heat load and furnace operating point were designed for a substantially higher temperature rise (approx. 27 Deg. C.). The blower-fan speed was therefore regulated by adjusting the pulley diameter. The static pressure and ΔT required were well within the range given in the furnace specifications, however when attempting to adjust the pulley, the setting required to attain desired temperature rise could not be reached because the pulley was already near its far limit. Given no other option, the pulley was adjusted to the limit which set the blower at the slowest rate. This in turn gave a temperature rise (25 Deg. C.) nearest to the desired value. A smaller pulley belt was required to securely fit the extreme point that the pulley was finally set to.

This problem is related to the fact that the selected furnace was sized according to both BTU output and static pressure required. Calculations of the static pressure in the system had determined that a high static unit (124.4 Pa compared with the regular 62.2 Pa pressure) was required.

Actual measurements have since shown that the lower static unit would have been better suited to the existing heating system and not have presented a problem with obtaining the correct temperature rise. Currently, the high static unit moves much more air (cfm) than if the appropriate static pressure did exist. As a result the air flows across the heat exchanger at a higher velocity, picks up less heat, and consequently enters the supply plenum at a lower temperature than if it was flowing at a lower velocity. If the correct static did exist to match the unit, the air velocity across the heat exchanger would be reduced correspondingly to within range to give the correct design temperature rise with minimal adjustment of the fan pulley diameter (adjustment of the pulley diameter increases or decreases air flow rate). Since this condition did not exist, the pulley diameter had to be adjusted to an extreme point to sufficiently reduce the air flow rate to give the design temperature rise.

In matching the equipment for test purposes, particular attention was given to bonnet capacity, air volume, temperature rise and static pressure. Inevitably, compromises had to be made in selecting the 'best' operation of the systems. No difficulty was found with respect to manufactured capacity availability (16.7 - 24.9 kw/hr).

The furnace itself is comparable to conventional equipment with respect to installation requirements, design and construction. For all practical purposes, any experienced heating contractor can be expected to install such a furnace. No difficulty was encountered with respect to the flexible venting other than the contractor not following the manufacturer's instructions which required that the vent be braced at every 0.91 m. The contractor was asked to make a return visit to the site in order to install a vent-brace. Special attention is

required with respect to the specifications regarding installation of the vent and vent terminal next to any combustibles. The fact that the venting is easily accessible and at walking level rather than through the ceiling, presents important safety implications. Consequently this could cause problems in finding acceptable locations for safe venting installation at some sites. It also points out the importance of stressing to contractors that the manufacturer's installation instructions be followed carefully since this furnace is a new product with different venting installation requirements than conventional units.

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REVIEWED BY: J. M. Jones

APPROVED BY: P. E. Dumouchel

APPENDIX A

Site Criteria

The following is a list of criteria required for each test site.

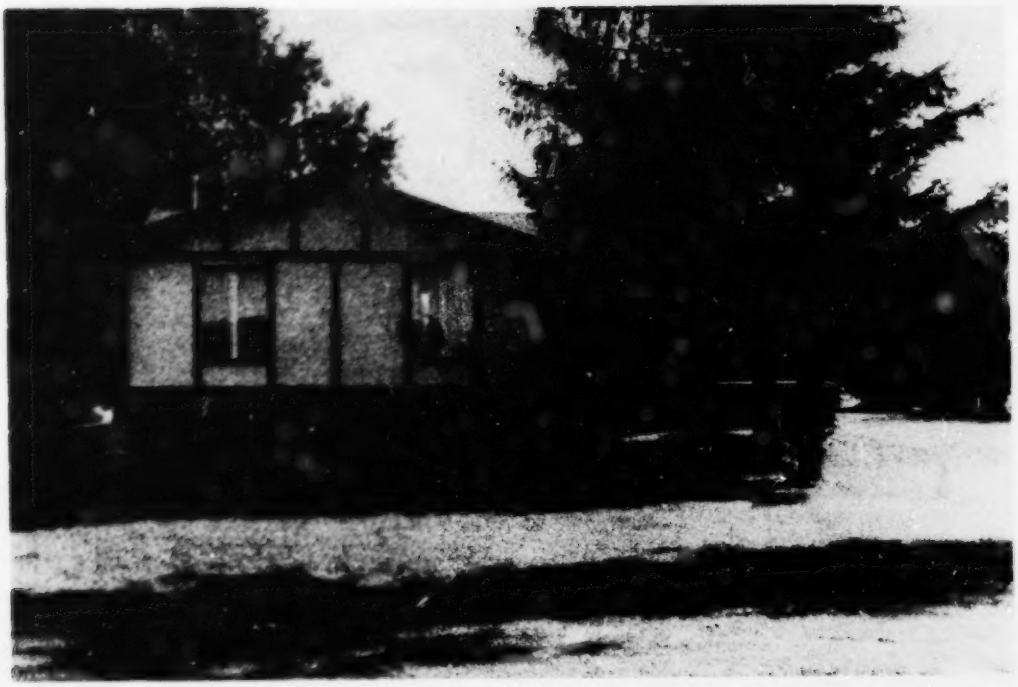
1. Natural Gas service must be available.
2. The home must be kept at a constant temperature during the heating season. No night setback is allowed.
3. Access to the home must be made available given reasonable notice.
4. The use of any other heating source other than those designated for the study such as a unit heater or fireplace is not permitted.
5. No energy savings alterations are to be done during the test (ie. caulking, weather stripping, insulating).
6. The space requirements of the new furnace are approximately 1.25 m x 0.52 m x 0.89 m with additional space provided for servicing.
7. The furnace area must be within 4.57 m of an outside wall.
8. The homeowner must be available to switch systems and record the required data, at or about, the same time each week.

Test Site Details

- Detached single family, single storey home with poured basement
- 170.4 sq. meters of living area
- Foundation built in 1978 with major construction finished in 1983
- 20.6 RSI (R-40) ceiling
- 10.33 RSI (R-20) walls
- Typical indoor setting 22 Deg. C.
- 15.2 KW calculated design heat loss (Heating unit selection value = design + 20% = 18.24 KW)
- No existing furnace
- Located in Chatham, Ontario, Rural area.

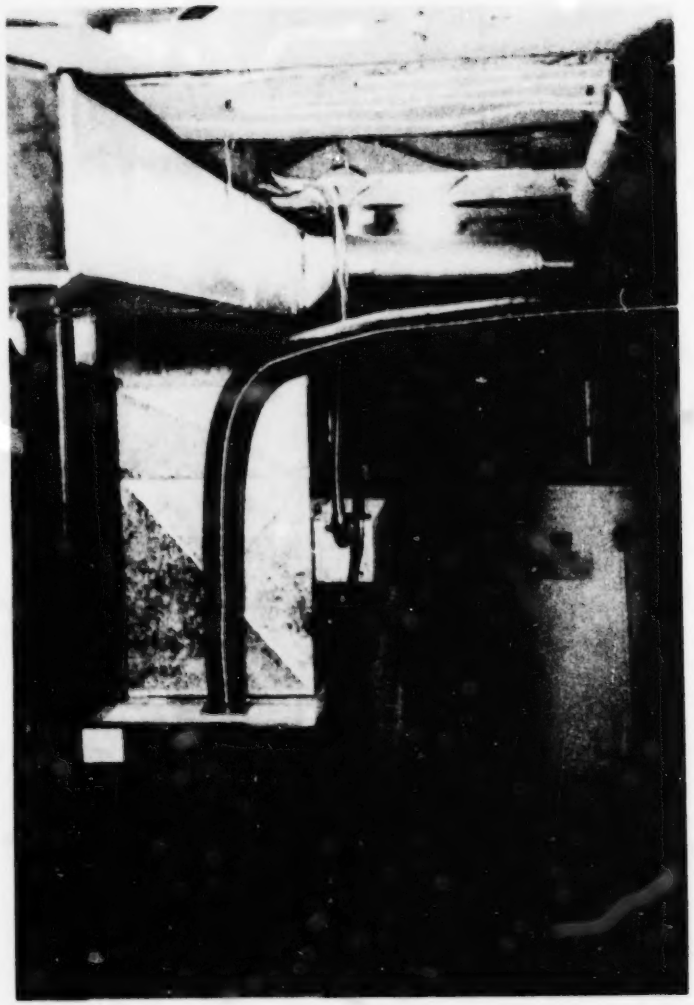
APPENDIX B

Installation Diagrams and Pictures

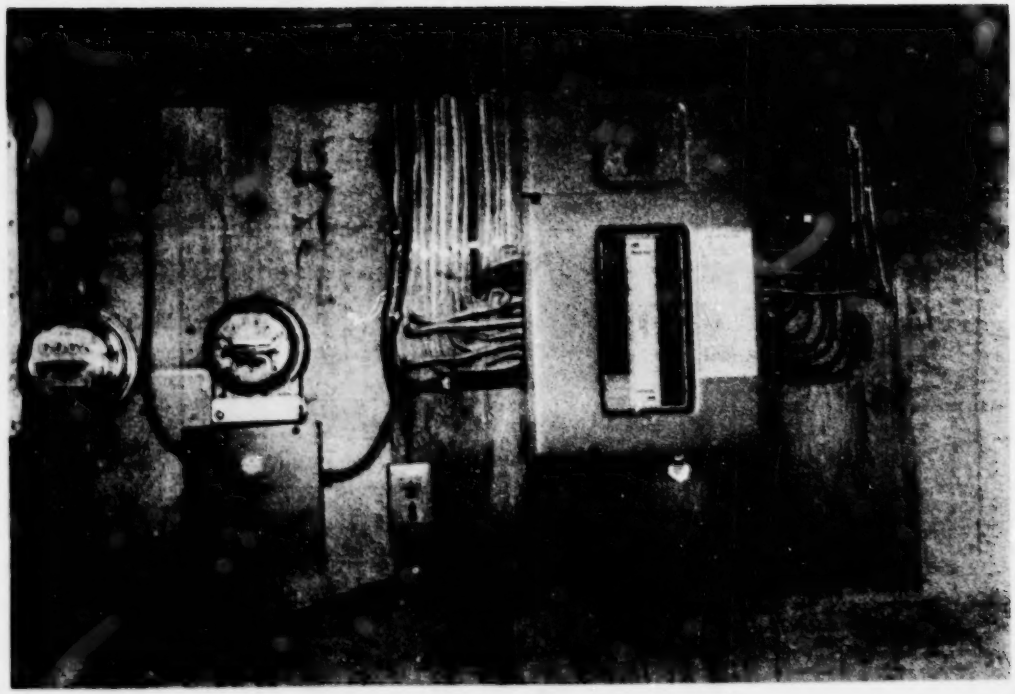


Site House Construction

Test Furnace Vent Terminal



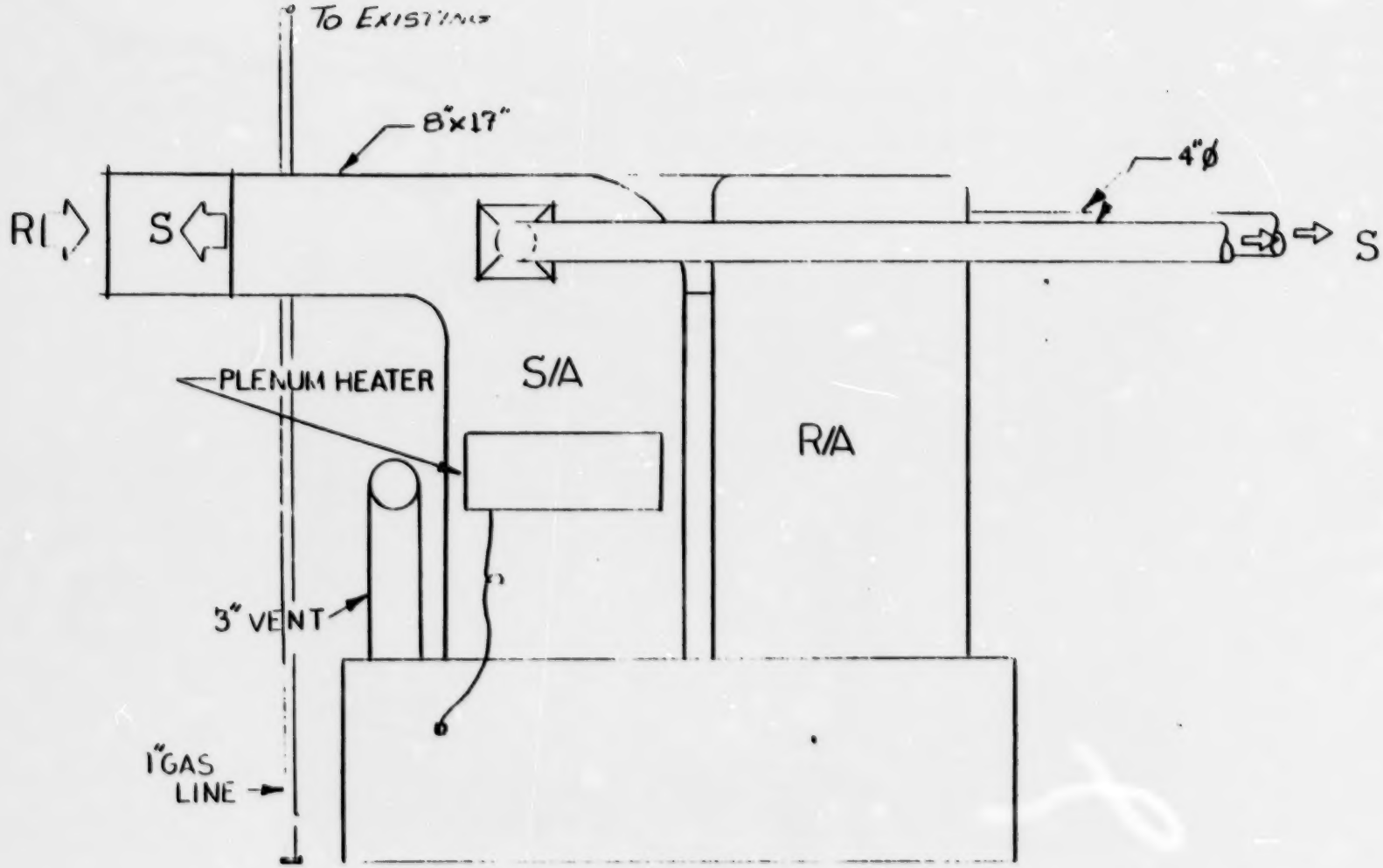
Grimsby Test Furnace Flexible Flue Pipe



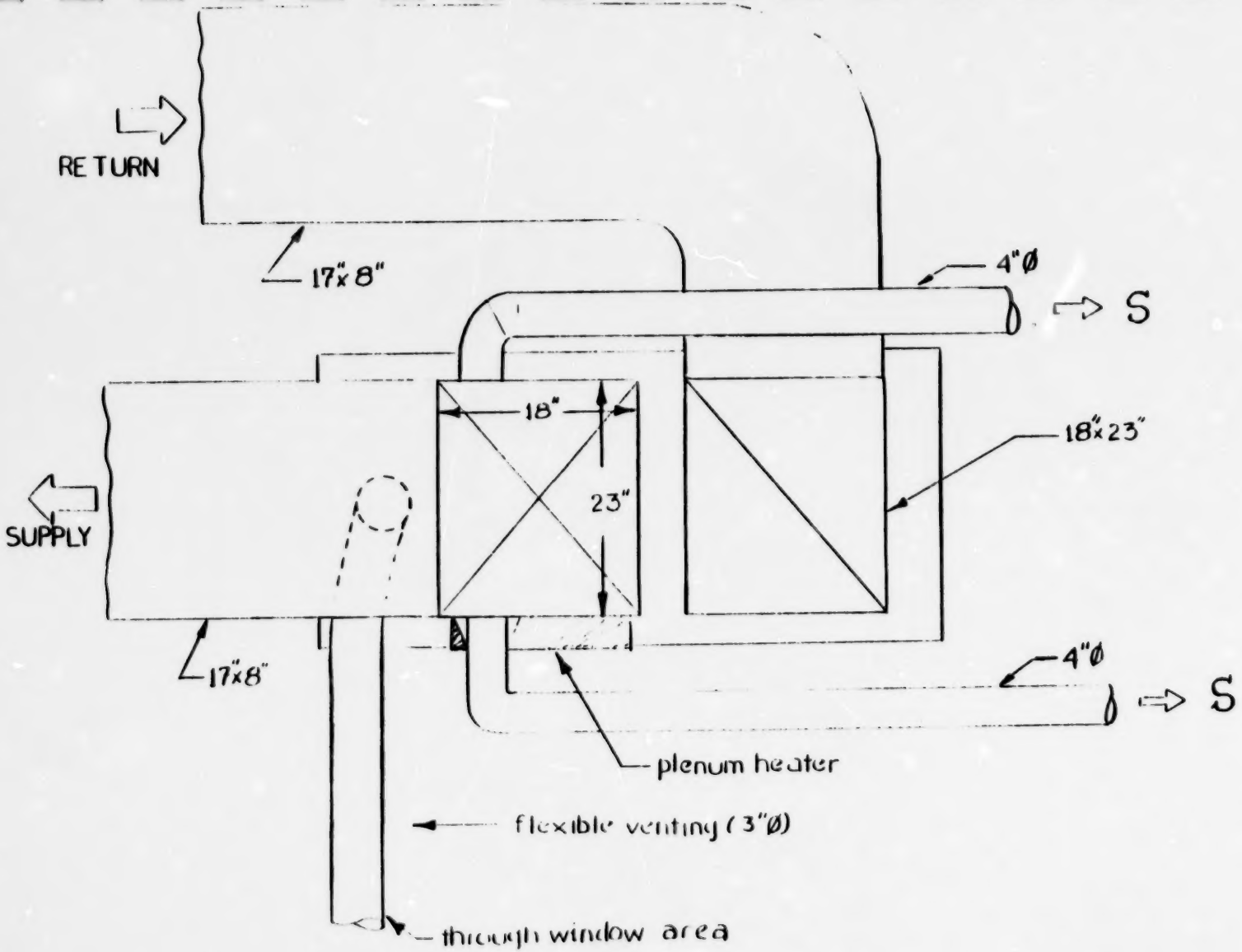
Left to Right:

220 V meter, 115 V meter, Gas-Electric operation switch, house panel board

NOTE: Thermostat anticipation correction circuit not installed at time of photograph.

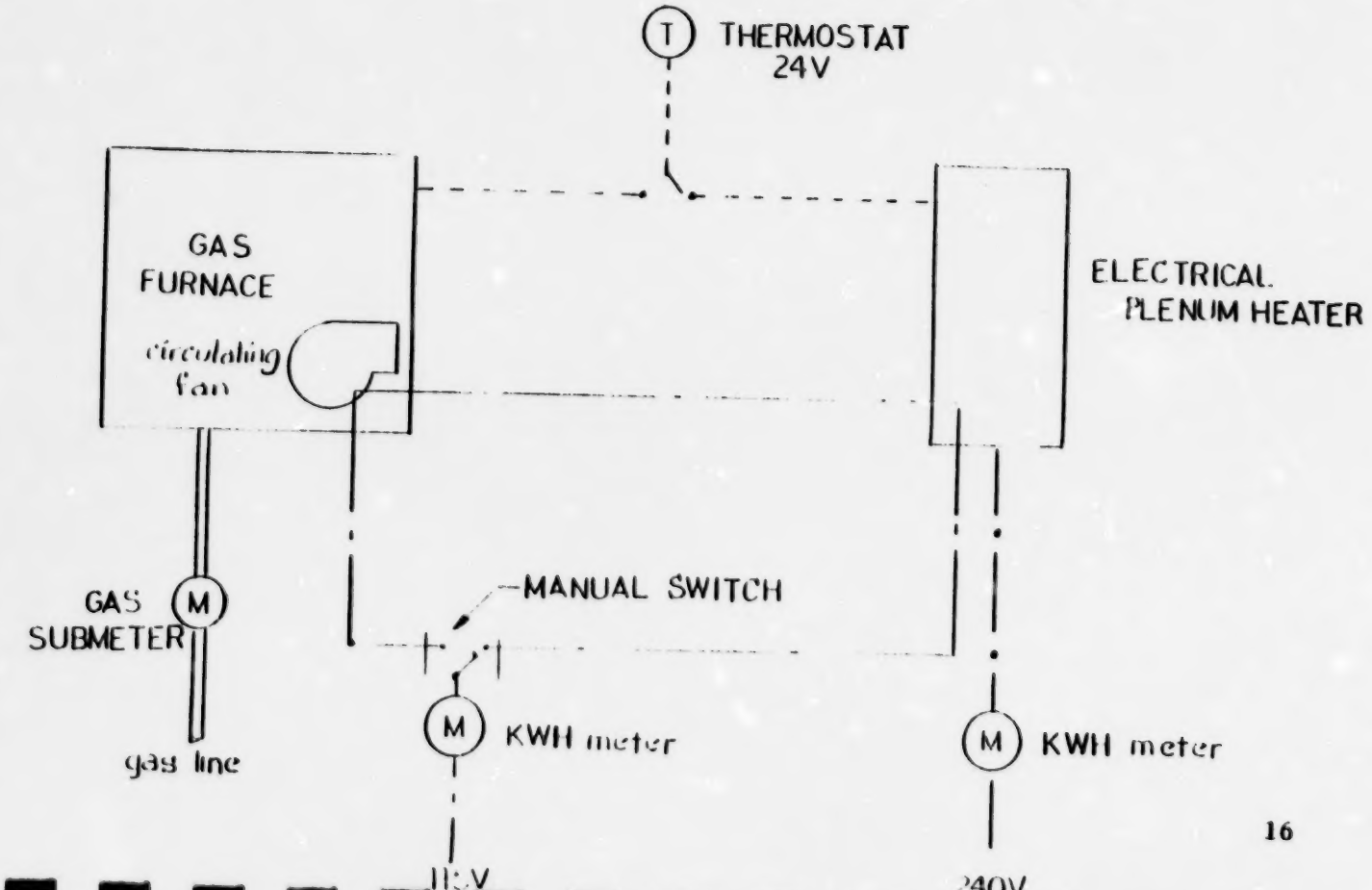


Installation Schematic - *Elevation*



-Installation Schematic -Plan

METERING SCHEMATIC



APPENDIX C

Data Sheets and Instructions

Furnace - Test Operation

GENERAL INSTRUCTIONS

a. The flip/flop changes are to be made on a weekly basis, at or near the same time each week, preferably between 7 and 11 p.m..

b. In alternating between gas and the electric, a data sheet (following) must be completed at the beginning and end of each period of operation.

c. Data is to be recorded on a daily basis, at or near the same time (between 7 and 11 p.m.).

d. Care must be taken in correctly reading the meters - see the example attached.

OPERATING STEPS

Electrical Plenum Heater

a. Turn gas OFF and record data for gas unit.

b. Flip electrical breaker for plenum heater at panel to ON position.

c. Flip control switch to Electric position.

d. Record preliminary electrical unit data.

High Efficiency Non-Condensing Gas Unit (Grimsby)

a. Flip electrical breaker at panel to OFF position.

b. Record data for electrical unit.

c. Flip control switch to Gas position.

d. Turn gas ON to furnace.

e. Record preliminary gas unit data.

TITLE: [redacted] EFFICIENCY FURNACE STUDY

LOCATION: _____

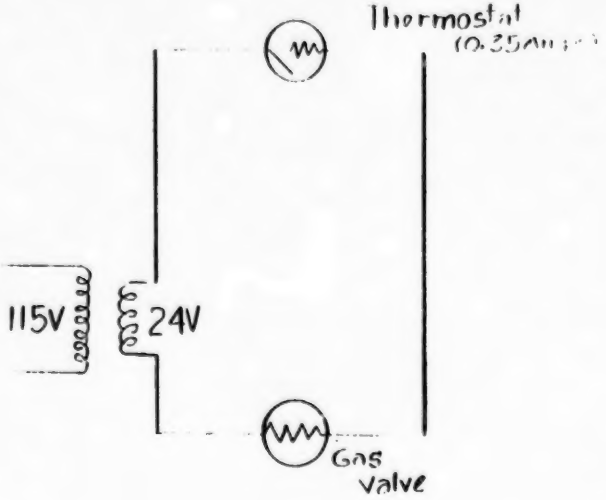
PERIOD: _____

INDOOR TEMPERATURE SETTING: _____

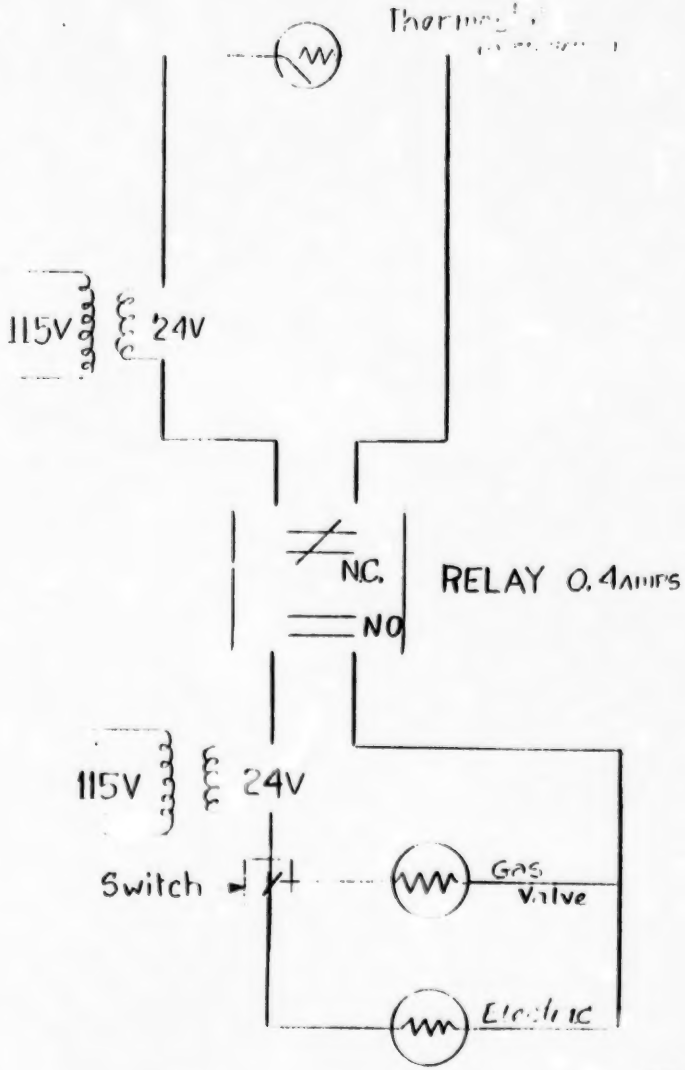
1.	2.	3.	4.	5. FURNACE -ON-		6. ELECT. CONS.		7. TEST FURNACE -GAS-		8. DEG. DAY ($18^{o}C$)	
DATE	TIME	TOTAL HOURS	Δ HOURS	ELECT.	GAS	115V METER	220V METER	RDG.	DIFF.	DD	DIFF.
YR/MO/D	HR.:MIN.					KWH	KWH	CU. FT.	CU. FT.	^{o}C	^{o}C

APPENDIX D

Anticipator Correction Schematic



Original



Corrected

Anticipator Correction Schematic

APPENDIX E

Equipment Details

Test Furnace

- Medium efficiency, non-condensing GRIMSBY unit
- Model 20055 H.S. Lo-Boy
- Rated

  Input = 21.975 KW

  Bonnet = 18.239 KW

  * Suggested Thermostat Anticipation = 0.35 Amps.
- Measured

  Temperature = 24.4 Deg. C.

  Input = 21.83 KW

  External Static Pressure = 89.58 Pa

* An isolating circuit has been installed to provide a constant 0.40 Amps to the thermostat.

Electric Plenum Heater

- P.S.C. Controls Ltd. electric conversion heater
- Model D20, 20 KW unit
- Requires 240 V.A.C. electrical service entrance
- Measured temperature rise T = 24.4 Deg. C.

Electric Meters

- Type CFA Westinghouse standard meter
- One 115 Volt, 10 amp. nominal unit
- One 220 Volt, 100 amp. nominal unit

Gas Meter

- Canadian Meter Co. Type AL 225
- 5.097 m^3/hr. air
- Litres computed at Temperature of 15.5 Deg. C.
- Pressure tested at 1.75 kPa
- Equipped with digital index accurate to 0.1 cu. ft.

APPENDIX F

Study Costs

REGULAR INSTALLATION COSTS

Gas Unit purchase (GRIMSBY) (includes venting, thermostat and vent terminal)	$1,439.00
Installation	$750.00
TOTAL	$2,189.00

STUDY RELATED COSTS

Plenum Heater (retail value)	$650.00
Electrical upgrading	$750.00
Monitoring Equipment:	
1 Gas Index	$36.16
2 Electric Meter bases, 2 x $24.08	$48.16
Electric/Metering Installation	$385.00
TOTAL	$1,869.32

Notes

1. The purchase prices of the furnaces are approximate in that they represent a typical retail price; actual prices may vary. These prices include freight and taxes.
2. Installation costs quoted by the contractor, include all labour, materials and taxes.
3. Duct work was not included in this cost study as this charge was considered a factor specific to this particular house construction and thereby not applicable to other house constructions.
4. Costs are as of this writing and subject to change upon receipt of all invoices.